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(54) OPTICAL SYSTEM

(71) We, XEROX CORPORATION of Xerox Square, Rochester, New York State, United States of America, a body corporate organized under the laws of the State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an optical system for forming images and more specifically to an optical system capable of super-imposing separate images on a common line or area at the imaging point.

There are many applications wherein it is desired to superimpose images obtained from two separate originals on a common line or area at an imaging point. One such application is in a photoelectrophoretic imaging system which is described in detail in U.S. Patents Nos. 3,383,993; 3,384,565 and 3,384,566. In photoelectrophoretic imaging, generally speaking, a layer of an imaging suspension comprising electrically photosensitive pigment particles in a carrier liquid is arranged between two electrodes, one of which is at least partially transparent, exposed to an imagewise pattern of activating electromagnetic radiation corresponding to an original image to be reproduced and subjected to an electric field whereby complementary images are formed on the surfaces of the electrodes.

Typically the imaging area is smaller than the area of the imaging suspension in order to ensure that the complete image is reproduced. However this usually results in a dark or colored border being formed around the reproduced image which is undesirable in a commercial imaging system. Thus, it would be desirable to be able to project a white border simultaneously with the projection of the original image on the suspension layer.

Previously known schemes for accomplishing superimposition of images at a common imaging point having typically utilized beam splitters. However beam splitter arrangements, as is well known, typically work at less than 50% efficiency. Thus to obtain a desired level of illumination at the imaging plane roughly twice that desired illuminance must be provided to illuminate the original image. In a commercial imaging system an optical arrangement which operates at less than 50% efficiency would require considerably higher power levels to provide the necessary illuminance at the imaging point. This type of an arrangement would obviously be highly disadvantageous from an economical viewpoint. Furthermore, cooling of the equipment in such an arrangement could become a troublesome problem, necessitating additional apparatus and thereby undesirably complicating the overall device configuration. Thus, in an instance such as that described above it would be desirable to have a method for superimposing optical images which operates at substantially full optical light efficiency.

According to the invention there is provided an optical apparatus including the following elements disposed along an optical axis: (a) an objective lens positioned at a distance hereinafter referred to as an object distance from an object plane and at a distance hereinafter referred to as an image distance from an image, plane, (b) a plurality of reflecting means positioned equidistant between said objective lens and said image plane, said reflecting means lying symmetrically about said optical axis and having their reflecting surfaces facing said optical axis, and (c) a mask disposed adjacent said object plane and defining a plurality of apertures for the passage through said apertures of light from said object plane, each reflecting means corresponding to a different aperture and being separated from the optical axis by half the distance by which the image of the light from the object plane through the corresponding aperture would be separated from the optical axis in the absence of the reflecting means, whereby light rays propagating from said object plane through said apertures are images at said image plane in upright and overlapping position.

Examples of the invention will now be

described with reference to the accompanying drawings wherein:

Fig. 1 is a partially schematic cross-sectional view illustrating a preferred embodiment of the invention; and

Fig. 2 is a partially schematic cross-sectional view illustrating another preferred embodiment of the invention.

Referring now to Fig. 1 there is seen a scanning carriage 10 positioned at a film plane 11 and which moves in the direction indicated by the arrow. The scanning carriage is capable of carrying at least two separated original objects, and original objects 12 and 14 are shown for the purpose of illustration. The originals whose images which can be superimposed at a common point according to the optical system of the invention are typically provided in the form of transparencies and, in a preferred instance, may be a 35 mm original slide and a border generating slide. Although the invention is described, in this illustrative instance, with respect to the slit-scanning mode of operation it should be recognized that it may be employed for full frame projection without scanning. Adjacent to scanning carriage 10 is located a fixed slit mask, generally designated 16, having slits 18 and 20. Original images 12 and 14 are positioned in the scanning carriage so as to arrive simultaneously at slits 18 and 20 respectively. As the scanning carriage transports the original images 12 and 14 past slits 18 and 20 respectively, the images are illuminated by means of light sources 21 located behind the scanning carriage.

Although the invention is being described in detail with respect to the superimposition of original images which are in the form of transparencies it will, of course, be obvious to those skilled in the art that when the system is utilized to operate with opaque documents the light sources 21 will be positioned on the opposite side of the imaging position from that shown.

The illuminated images at slits 18 and 20 are viewed by fixed projection lens 22. Projection lens 22 typically has a wide enough field to pick from both of the illuminated images 12 and 14. The fixed lens 22 projects the illuminated images to two flat mirrors 24 and 26 located equidistant from the lens center and the imaging plane 28. Mirrors 24 and 26 are preferably first surface mirrors having reflecting surfaces 24′ and 26′ respectively and are mounted plane parallel to each other and, to the slits 18 and 20, and parallel to the optic axis 30 and equally spaced therefrom. First surface mirrors, i.e. those having a reflecting coating on one of the glass surfaces which is usually a vacuum deposited aluminum film protected by a thin transparent overcoating of silicon monoxide, are typically necessary to prevent "ghost" images from being formed at the imaging plane. The mirrors 24 and 26 reverse the sense of the projected images from slits 18 and 20 respectively and direct the projected images to the final imaging area 31 at the imaging plane. Of course any light reflecting materials such as, for exmple, prisms may be used according to the invention. Positioned between mirrors 24 and 26 is optional light baffle 32 which is preferably arranged to prevent any undesired light from reaching the imaging plane.

The projected images are directed through slit 34 of fixed imaging slit mask 36 and are superimposed at the final imaging area 31 on the image receiving member 35 which is located at the imaging plane 28. The image receiving member 35 may be any of many different materials such as, for example, a photoconductive insulating surface, a photographic film, a traveling web, etc. Of course where the scanning mode of operation is practiced and the scanning carriage 10 moves in the direction of the arrow, the image receiving member 35 will also be moved in the direction of the arrow. Alternatively the scanning mode of operation may also be practiced by holding the scanning carriage 10 and image receiving member 35 fixed and moving the other elements of the apparatus with relation to them.

Any desired magnification can be obtained by adjusting the spacing of the various elements of the optical system. The following discussion concerning the arrangement of the elements of the system will be illustrative.

Let Y designate the spacing between the two original transparencies at the viewing slits 18 and 20. Then by geometric triangulation, the spacing between the projected real images 40 and 42 will be MY where M is the magnification ratio. Also by geometry, the spacing between the two mirrors 24 and 26 and the axis 30 will be

$$\frac{MY}{2}.$$

Using the common lens formulae, the relations between object distance, image distance, focal length and magnification can be readily established as follows: if X represents the object distance, then MX will be the image distance and

$$\frac{1}{X}+\frac{1}{MX}=\frac{1}{F}$$

where F is the focal length of the lens. Then

$$F=\frac{MX}{M+1},\quad X=\frac{F(M+1)}{M}$$

and $MX = F(M+1)$ so that one variable can be determined if the other two variables are known. It is seen that both of the images projected by fixed lens 22 to the mirrors 24 and 26 define an angle α with respect to the optic axis 30. Angle α can be expressed in terms of X and Y since

$$\alpha = \tan^{-1} \frac{Y}{2X}.$$

The optical system of the present invention can operate at various magnifications as has been seen. However the system becomes large and unwieldy as the ratio of the conjugate becomes larger. In a preferred embodiment of the invention wherein the novel optical system is employed to produce enlarged reproductions from relatively small (e.g. 35 mm) transparencies it is particularly preferred to use magnifications in the general range of 1:2 and 1:8. Where the optical system is used to reproduce opaque originals a magnification ratio of 1:1 will usually be preferred. For example, document copying equipment, either of the scanning type or the fullframe exposure type typically requires the copy to be about the same size as the original. Of course it will be recognized that the optical system may be used in a demagnification mode where it is desired to form optical images at the imaging plane which are smaller than the original objects sought to be superimposed.

It will be further appreciated by those skilled in the art that when the slit scanning mode of operation is practiced with a moving scanning carriage and a moving optical image receiving member and the system is arranged for a 1:1 magnification ratio, the scanning carriage and the optical image receiving member will typically be moved in the same direction at the same speed. If the same mode of operation is practiced with a different magnification ratio then the optical image receiving member will typically be moved at a different ratio of speed relative to the scanning carriage corresponding to the particular magnification ratio used. For example if a magnification ratio of about 1:3 is used the optical image receiving member will typically be moved at a rate about three times faster than the rate at which the scanning carriage is moved.

Fig. 2 illustrates the practice of the invention in the frame projection mode. The apparatus shown in Fig. 2 is similar to that shown in Fig. 1 with like elements being designated with like numerals. In this mode of operation the object carriage and the image receiving member are stationary. It will be noted that slits 18′ and 20′ of fixed slit mask 16′ and slit 34′ of fixed imaging slit mask 36′ are larger than the corresponding slits in Fig. 1.

Although the optical system has been described with respect to a preferred embodiment of the invention wherein the optical system is advantageously utilized to superimpose projected images from two separated original images it should be recognized that it may also be used to generate two identical separated images from a single original object. According to this embodiment of the invention the apparatus configuration is identical with that shown in Fig. 1 and Fig. 2 with the exception that the object plane and the imaging plane are reversed. In other words the object plane shown in the drawing becomes the imaging plane and the imaging plane becomes the object plane. Of course the light sources must illuminate the original object at the film plane.

While the novel optical system has been described in detail with respect to simultaneous superimposition of transparencies it will be readily apparent that the invention is not limited to this embodiment. Images of illuminated opaque documents may be projected and superimposed using the same optical elements and arrangements and this may be accomplished in either the moving slit-scanning mode or, preferably, the fixed full-frame mode. It will also be apparent that a further capability of the novel optical system resides in the superimposition of images from an illuminated opaque document and an illuminated transparency.

WHAT WE CLAIM IS:—

1. An optical apparatus including the following elements disposed along an optical axis:

a) an objective lens positioned at a distance hereinafter referred to as an object distance from an object plane and at a distance hereinafter referred to as an image distance from an image plane,

b) a plurality of reflecting means positioned equidistant between said objective lens and said image plane, said reflecting means lying symmetrically about said optical axis and having their reflecting surfaces facing said optical axis, and

c) a mask disposed adjacent said object plane and defining a plurality of apertures for the passage through said apertures of light from said object plane, each reflecting means corresponding to a different aperture and being separated from the optical axis by half the distance by which the image of the light from the object plane through the corresponding aperture would be separated from the optical axis in the absence of the reflecting means, whereby light rays propagating from said object plane through said apertures are imaged at said image plane in upright and overlapping position.

2. An optical apparatus as claimed in claim 1 in which said object distance is a value X, said image distance is MX (where M equals the lateral magnification of the system), said apertures are spaced apart on their centres by a value Y, and said reflecting means are correspondingly spaced apart by a value $\frac{1}{2}$MY.

3. An apparatus as claimed in claim 1 or claim 2 wherein the magnification ratio is from 1:2 to 1:8.

4. An apparatus as claimed in claim 1 or claim 2 wherein the magnification ratio is 1:1.

5. Optical apparatus substantially as hereinbefore described with reference to either Figure of the accompanying drawings.

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1395580 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

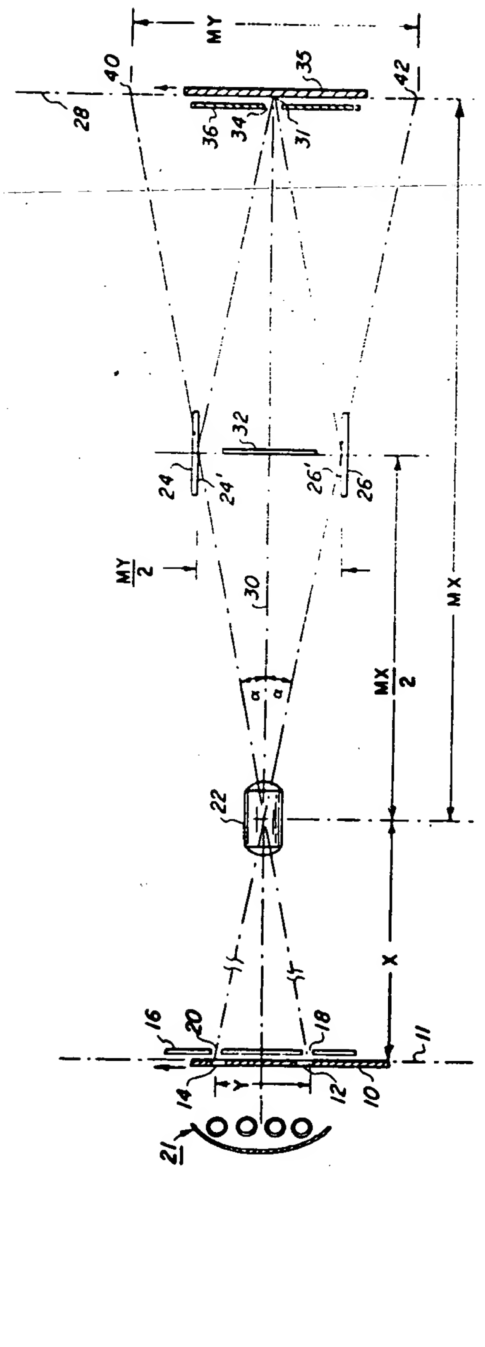

FIG. 1

1395580 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

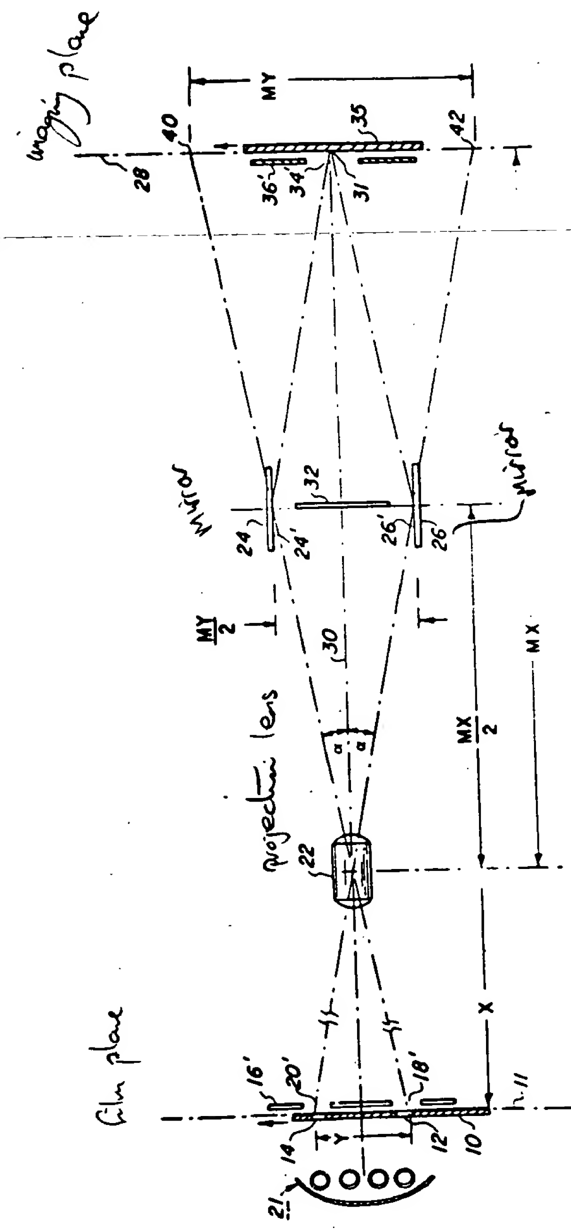

FIG. 2